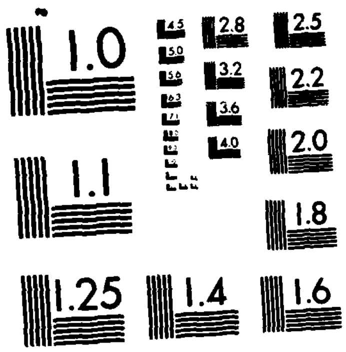
AD-A162 947 LIGHTNING AT KENNEDY SPACE CENTER(U) EASTERN SPACE AND MISSILE CENTER PATRICK AFB FL W C GIBBONS ET AL 1985 ESMC/TR-85-07 1/1

UNCLASSIFIED F/G 4/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A162 947

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	UNCLASSIFIED/UNLIMITED
1b. RESTRICTIVE MARKINGS	NONE
2a. SECURITY CLASSIFICATION AUTHORITY	N/A
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	N/A
3. DISTRIBUTION/AVAILABILITY OF REPORT	"A"
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	ESMC/TR-85-07
5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION	EASTERN SPACE AND MISSILE CENTER (ESMC)
6b. OFFICE SYMBOL (If applicable)	WE
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State and ZIP Code)	ESMC/WE PATRICK AIR FORCE BASE, FL 32925
7b. ADDRESS (City, State and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	Eastern Space and Missile Center (ESMC)
8b. OFFICE SYMBOL (If applicable)	
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	N/A
8c. ADDRESS (City, State and ZIP Code)	
10. SOURCE OF FUNDING NOS.	PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.
11. TITLE (Include Security Classification)	Lightning at Kennedy Space Center
12. PERSONAL AUTHOR(S)	William C. Gibbons, Billie F. Boyd
13a. TYPE OF REPORT	Progress
13b. TIME COVERED	FROM 1984 TO 1985
14. DATE OF REPORT (Yr., Mo., Day)	
15. PAGE COUNT	5
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Lightning, Thunderstorms, Space Shuttle, Weather Sensitivities

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Lightning frequency and importance at the Kennedy Space Center (KSC) and the Eastern Test Range (ETR) are discussed. The lightning detection systems in use and their importance to Space Shuttle operations are presented. Lightning research projects are briefly mentioned.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐
21. ABSTRACT SECURITY CLASSIFICATION	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL	William C. Gibbons, 1Lt, USAF
22b. TELEPHONE NUMBER (Include Area Code)	305-494-5915
22c. OFFICE SYMBOL	WER

DD FORM 1473, 83 APR

EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

85 12 31 009

LIGHTNING AT KENNEDY SPACE CENTER

William C. Gibbons and Billie F. Boyd
Office of the Staff Meteorologist
Eastern Space and Missile Center
Patrick Air Force Base, Florida

William Jafferis
Office of the Directorate of Launch
and Landing Operations
John F. Kennedy Space Center, Florida

ABSTRACT

Lightning frequency and importance at Kennedy Space Center are discussed. Lightning detection systems and research projects are described.

BACKGROUND

The Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) area borders the area of highest frequency of thunderstorms in the United States (Fig. 1[1]). Since the majority of the thunderstorms occur in the summer months, lightning frequencies in the area during these months approach the highest level of any location in the world. The mean area density of cloud-to-ground lightning at KSC is 3.9 with a range of ± 2.4 flashes per square kilometer during June, July, and August[2]. If the lightning strikes were randomly spaced, this would equate to about 10 ± 6 lightnings for each square mile of KSC each month, or a total of about 1400 ± 840 lightning strikes each summer in the KSC area. This high level of frequency presents three major problems: danger to personnel, damage to equipment and property, and loss of time in order to minimize the previous items.

Danger to personnel is very real. Over the period 1959 to 1983 there were 245 deaths in Florida attributed to lightning (approximately ten per year, more than ten percent of the national total[3]). There were 663 lightning related injuries reported in that same period within Florida, which again equals approximately ten per cent of the national total of 6,219[3].

Loss of production time due to lightning occurrence has been a problem since the origin of the space program at KSC/CCAFS. Holmes[4] documented the problem as early as 1964 and Goodman[5] recently discussed the effect of lightning on all phases of Shuttle operations.In preparation for the Shuttle program, the National Aeronautics and Space Administration (NASA) at KSC improved the lightning protection systems for critical work areas and changed their ground safety plans.

The United States Air Force's (USAF) Detachment 11, 2d Weather Squadron of the Air Weather Service (AWS) is constantly working with the various offices of NASA at KSC and the USAF's Eastern Test Range (ETR) and CCAFS to further minimize these problems through improved instrumentation to inhance understanding and forecasting of lightning. NASA has also supported a variety of lightning research projects.

LIGHTNING DETECTION SYSTEMS

Two major lightning detection systems currently in use in the KSC/CCAFS area are the Launch Pad Lightning Warning System (LPLWS) and the Lightning Location and Protection (LLP) system.

Launch Pad Lightning Warning System (LPLWS). The LPLWS was developed as a result of lightning discharges to Apollo 12[6]. The LPLWS enables forecasters to monitor impending and current atmospheric electrical activity. It provides the USAF weather forecasters information on trends in electric field potential and on locations of highly charged clouds and charge centers associated with lightning. This information is used to alert launch complexes and operational areas at KSC so appropriate protective actions can be taken. The LPLWS consists of 34 electric field mills (Fig. 2), computer software for data acquisition and analyses, and a CRT display.

The field mills are placed so the sensor plate is ten inches above the ground. They measure the vertical component of the atmospheric potential gradient at ground level. Each field mill contains eight vertically oriented stator sections which are alternately covered and uncovered as the rotor turns. The differential voltage (volts per meter) between the covered and uncovered stators provides the amplitude and polarity of the electric field. The dynamic range of the sensors is ±15 kilovolts per meter. The data from each field mill are transmitted to a central area where they are digitized at a rate of ten samples per second.

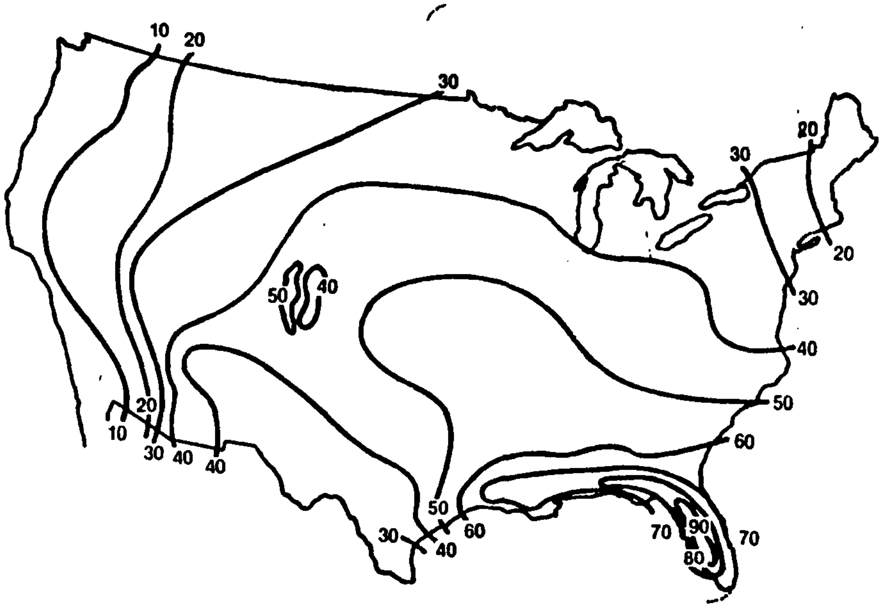


Fig. 1 Mean Annual Thunderstorm Days, 1951-1975.

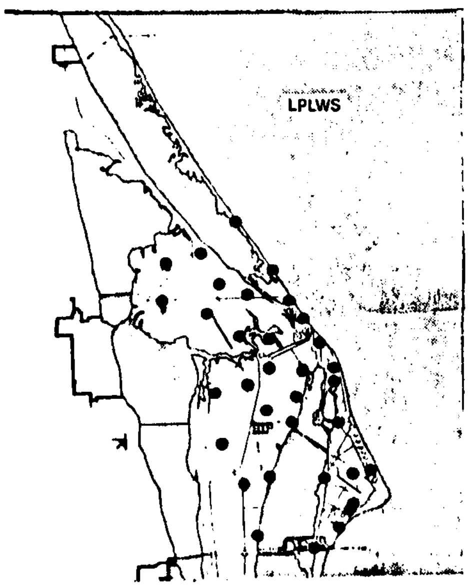


Fig. 2 Field Mill Locations.

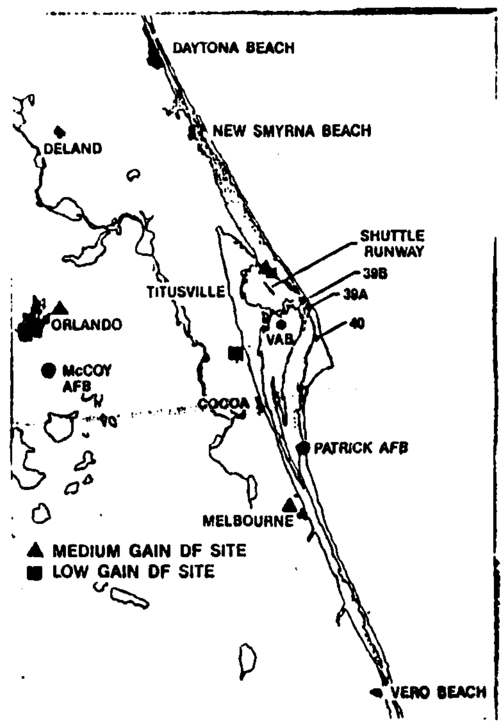


Fig. 3 DF Site Locations.

The LPLWS computer software has a static field mode and a lightning mode. The LPLWS static field program contours the field mill data so the forecasters can determine when the electric field values indicate the threat of lightning is imminent. A map of the CCAFS/KSC area is drawn and contours of the static field are plotted on a CRT. The static field is calculated from the average electric field value at each mill during a 1 minute interval; the forecasters can specify output intervals of 1 to 60 minutes (default is 15 minutes). The average field value for each field mill is printed on the right side of the contour map. During lightning activity the static fields are no longer useful and the lightning mode locates intercloud and cloud-to-ground lightning strikes. In the lightning mode, the LPLWS program outputs the charge centers or source of lightning activity. The program checks for lightning discharge by evaluating data over two one tenth of a second intervals which is accomplished by extrapolating the slope (assumed to be linear) of the field in the first one tenth of a second interval to a predicted value at the end of the next one tenth of a second interval and comparing this to the measured field at that point. If the difference between these two values is greater than 600 volts/meters at two or more sites, a lightning discharge is assumed. The exact time of the strike, the initial and final field, and the field change at each site are then determined. The center of the field change over the network is calculated and this is interpreted as the source of the discharge in the cloud. The first discharge center detected in each 15 second interval is displayed on the CRT. At the end of each minute, the total number of lightning discharges during the preceding one minute interval is output to provide additional information on each storm's lifecycle. After five minutes, the screen is erased, another static field display is output, and the cycle is repeated if more lightning discharges are detected.

The most significant use of the LPLWS is during launch and landing of the Space Shuttle. Shuttle launch commit criteria related to lightning are listed in Table 1[7]. The intent of these rules is to protect the Shuttle vehicle from lightning strikes (like the Apollo 12 strikes). The LPLWS is used to detect the potential for lightning strikes to the Shuttle during launch or landing. It is an essential instrument for lightning detection at KSC.

TABLE 1

SHUTTLE LAUNCH COMMIT CRITERIA

RELATED TO LIGHTNING

The Shuttle vehicle shall not be launched if the nominal or the return to launch site flight path will carry the vehicle:

a. Through clouds in the dissipating stage where such clouds have activated the ground level delta field contours (discharges) within a period of 15 minutes before launch. (The maximum ground level electric field at the launch or landing site must not exceed 1 kilovolt per meter.)

b. Through any cloud if a 1 kilovolt per meter or greater ground level electric field contour encompasses the launch or landing site.

Lightning Location and Protection (LLP) System. The LLP system locates cloud-to-ground lightning in the KSC/CCAFS area and complements the LPLWS which can locate charge centers, but not actual ground strike locations. The detection efficiency of the LLP system has been estimated between 74 and 90 percent[8,9]. The LLP system at KSC consists of two independent systems: a low gain and a medium gain system.

The low gain system has two direction finder (DF) antennas, one located at Titusville-Cocoa Airport and the other on North KSC (Fig. 3). The low gain DFs were placed to give maximum position accuracy around Complex 40; these DF antennas can accurately detect lightning from 10 to 100 kilometers. The low gain system detects both positive and negative charges. The location accuracy of the low gain system is about 100 meters. The medium gain system has three DF antennas located at Melbourne Airport, Orlando Airport, and North KSC (Fig. 3). These DF antennas detect lightning from 20 to 200km and detect only lightning that lowers negative charges. The medium gain system locates lightning to an accuracy of about 500 meters[10]. Lightning strike positions detected by the medium gain system are processed through a position analyzer (PA) and a remote display processor (RDP) to be viewed on a color video display unit at the Cape Canaveral Forecast Facility (CCFF). The RDP allows the forecasters a variety of maps and modes for displaying the lightning. The lightning strike positions from the low gain system are processed through a separate PA and plotted on a high resolution rectangular plotter at the CCFF. A local data terminal for each system records the time, location, polarity, and number of return strokes for each detected cloud-to-ground lightning strike. The data for the low gain system is recorded on a Columbia 8-track recorder; the medium gain data is recorded on the Columbia recorder and a Cipher 9-track recorder.

Each DF antenna site uses an orthogonal set of magnetic loop antennas and a flat plate electric field antenna to sense the electromagnetic field radiated by lightning discharges. The bandwidth of the antenna system is broad, approximately 1 kilohertz to 1 megahertz, which preserves the shape and polarity of the lightning waveform. The system processes only those fields that have wave shapes and polarities characteristic of cloud-to-ground lightning. The direction of the incoming field is determined at each DF site from the ratio of the signals on the two orthogonal loops. By measuring the direction at just the time when the return stroke magnetic field reaches its initial peak, errors due to horizontal channel sections are minimized. This time also corresponds to a point where the return stroke is within 100 meters of the ground, thus giving the location of the actual ground stroke rather than some elevated portion of the stroke. The DF sites communicate to their respective PA via half duplex lines.

The PA is a complete microcomputer that accepts data inputs from the DF sites and automatically reports the locations of the lightning strikes. The locations are computed by triangulation using the angles measured at two of the DF sites. Lightning which occurs along the baseline of two of the DF sites could be plotted inaccurately because of the small angles involved in the calculation. In the medium gain system, this problem is overcome by selecting the third DF site as the primary input in conjunction with one of the other two DF antennas. If a third input is not available (as in the low gain system), the position is computed by comparing the field amplitude at each DF site as well as each angle.

The USAF forecasters use the medium gain LLP system to determine which echoes on radar are producing lightning and when these, or other thunderstorms, will be affecting the KSC/CCAFS area. This system helps determine when lightning warnings should be issued so personnel can take proper protective action. For example, the Tethered Aerostat Radar System (TARS) at CCAFS requires a leadtime of 1 hour for thunderstorms within 25 nautical miles and the Shuttle, if it is on the pad, requires 30 minutes of leadtime for lightning within 5 nautical miles of Complex 39A or 39B[11]. The LLP system is also used to determine when lightning warnings should be canceled so as to minimize loss of work time.

RESEARCH PROJECTS

KSC has evolved as an important location in lightning research due to its high frequency of lightning strikes as well as sophisticated lightning detection systems. During the summer of 1985, 36 lightning researchers conducted their studies at a facility located about 9 miles north of the KSC Vehicle Assembly Building. Taking part in these research projects were representatives of NASA, the USAF Wright Aeronautical Laboratory (AFWAL), the US Naval Laboratory, France's Center for Nuclear Studies, American universities, and private industry. Information gained in these studies may eventually be used in the design of advanced lightning protection systems for KSC/CCAFS facilities and also for greater protection of aerospace vehicles containing electronic flight control systems, such as the Shuttle.

The French scientists trigger lightning by launching a small rocket which trails a thin copper wire to an altitude of about 3,000 feet. The wire acts as a trigger, attracting the stroke which vaporizes the wire while traveling down an electrical pathway to the ground. Special instruments and cameras near the launch site record the strike in detail. Triggered lightning provides a degree of control of lightning events occurring at a known ground location thereby providing a laboratory quality set of measurements to correlate with existing operational and scientific instrumentation.

A joint project between the Federal Aviation Administration and the AFWAL continued in 1985. One of the objectives was studying the effects of lightning on flying aircraft using a specially equipped Convair C-580 airplane; the researchers hoped to position it beneath a charged cloud. Ideally a stroke of triggered lightning would descend from the cloud, pass directly through the aircraft, and to the ground providing instruments on the plane and the ground with measurements of the lightning strike.

The research included studies sponsored by three universities. The University of Florida sponsored a study of the electric field to determine lightning strike effects to aerial power and buried telephone lines. Electric Power Research Institute and Bell Laboratories supported the University of Florida on this project. Additionally, the University of Florida attempted to gain three dimensional photographs of lightning strikes. By placing three video cameras at various angles and distances from the triggered lightning site, researchers hoped to obtain three dimensional images with which to correlate the electric field data. A team from the University of Arizona studied the Maxwell current. The current develops in a particular pattern before, during, and after thunderstorms. In the future this may help forecasters predict the start and end of thunderstorms more accurately. A group of researchers from the State University of New York at Albany used a streak camera to determine return stroke velocity.

The Communication and Weather Research Foundation provided support and communication equipment for all phases of these research projects.

SUMMARY

Lightning activity in the KSC/CCAFS area is both a curse and a blessing. The high lightning frequency is a threat to life and slows space vehicle operations. Yet, the presence of numerous lightning strikes as well as sophisticated lightning detection systems make KSC an ideal location for lightning research to perfect lightning detection and protection.

REFERENCES

1. Court, A. and J. F. Griffiths, (1982): "Thunderstorms: A Social, Scientific, and Technological Documentary, Vol 2, Thunderstorm Morphology and Dynamics, E. Kessler, Ed., NOAA/ERL.

2. Krider, E. P. (1981): Progress Report on NASA Contract.

3. Clary, M. (1985): Lightning! Spectacular and Deadly; Weatherwise, Vol 38, No. 3, pp 128-135.

4. Holmes, H. R. (1964): Meteorological Considerations Related to the Procedure for Protection of Personnel at Launch Complex 37 During Lightning Hazards.

5. Goodman, S. J. (1985): Real-Time Applications for Remotely Sensed Lightning Observations; Conference on Aerospace and Range Meteorology, 27-29 Aug 85.

6. Arabian, A. D. (1970): Aspects of the Apollo 12 Lightning Incident, Presented at the SAE/AFAL Lightning and Static Electricity Conference, San Diego, CA, 9-11 Dec 70.

7. Shuttle Launch Commit Criteria and Background, Revision C, 1 Dec 1982, NASA/JSC, pp 1.4-2-1.4-3, rule 1.4.8.

8. Goodman, S. J. et al (1985): Lightning Observations Above and Below Clouds: Comparisons with Storm Development, Radar and Satellite Data. Submitted to Journal of Geophysical Research.

9. Maier, M. W. et al (1984): Gated, Wide-Band Magnetic Direction-Finders for Locating Cloud-to-ground Lightning, Preprints VII International Conference on Atmospheric Electricity, Albany NY, 305-310.

10. Maier, M. W. and W. Jafferis (1985): Locating Rocket Triggered Lightning Using the LLP Lightning Locating System at the NASA Kennedy Space Center. Presented at 10th International Conference on Lightning and Static Electricity, Paris, France, 10-12 June 1985.

11. Weather Support Plan ESMC OPLAN 105-1, HQ Eastern Space and Missile Center, Patrick Air Force Base, Florida, 22 April 1985, pp B-1-4.

12. Weather Meteorological Handbook, ESMCP 105-1, HQ Eastern Space and Missile Center, Patrick Air Force Base, Florida, 9 Sep 82.

13. Lightning Research Continues at KSC, Spaceport News, Vol 24, No. 17, 16 Aug 1985, pp 7-8.

END

FILMED

2-86

DTIC